1.2 ***Monitoring Well Construction***

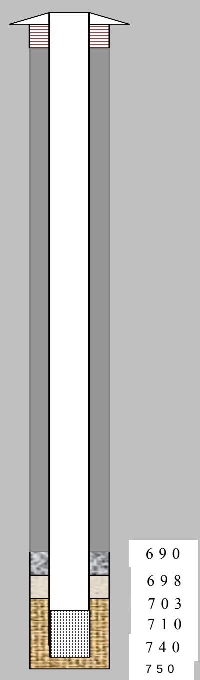
The USGS and/or Bernalillo County have drilled monitoring wells or deep nested piezometers within each of the areas previously described. *Monitoring well* installation typically involves the drilling of a 6- to 8-inch diameter rotary boring and installation of a single well string of 4-inch PVC casing with 20 feet or more of screen placed near the water table. In contrast, a *nested piezometer* is installed in a single larger-diameter borehole rather than using one borehole per well string. To accommodate multiple well strings, 2-inch diameter casing and screen are used and borehole diameters may be in excess of 12-inches. Screen length for each *piezometer* is typically no more than 20 feet. Long intervals of the annulus between the casing and hole are filled with bentonite and cement to separate the screened intervals. Figure 2.12 illustrates the difference in construction. At some locations, the USGS has installed *piezometer nests*, which consist of multiple nested piezometer locations and utilizing two or more boreholes, or which may consist of combinations of monitoring wells and nested piezometers, but located immediately adjacent to one another. The East Mountain, Far Northeast Heights, and the Paradise Road and 9 Mile Hill locations are monitoring well constructions, while the Rio Bravo Park and Isleta locations are piezometer-type construction.

Surface completion may be either "flush-mount" where the surface pad is at or slightly above ground surface, or the well or nested piezometer may "stick-up" into a protective above-ground casing. The flush-mount completion is advantageous for areas that are mown, near traffic, or where low visibility is desired. The aboveground completion precludes infiltration of water into the protective casing and is preferred for low-lying or poorly drained locations. Surface completions are also illustrated in Figure 2.12. With either surface completion, the wells are secured within locked protective casings or bolted well vaults to minimize vandalism.

1.3 ***Water Level Monitoring***

Water level data collection provides one method of quantifying the affects of drought and of ground-water withdrawals from aquifers and related water availability. It is also an essential data element needed for calibrating groundwater models used to identify the extent and amount of aquifer dewatering that will occur in the future and to evaluate the potential effects of new well installations.

Monitoring Well Construction (Flush Mount Completion)	Piezometer Nest and Nested Piezometer Construction



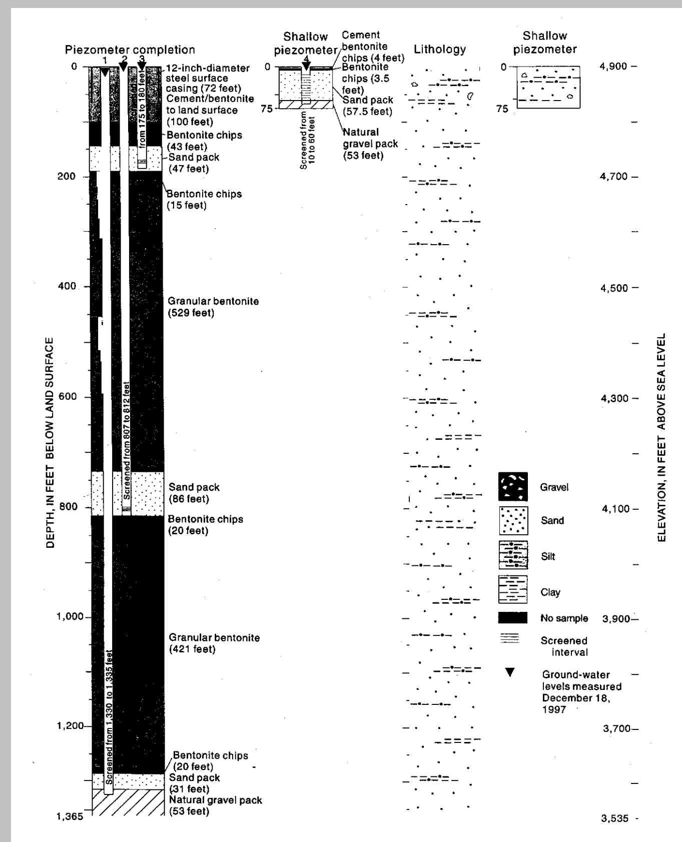
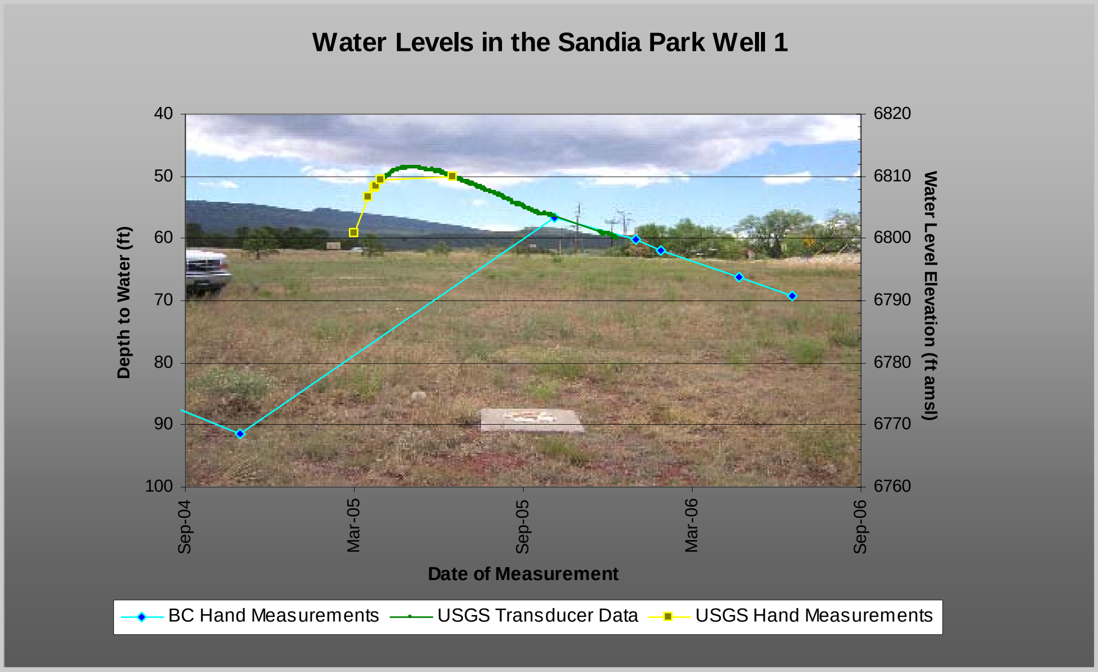


Figure 2.12 Examples of Monitoring Well and Nested Piezometer Constructions

Water levels can be measured in a variety of ways (see Figure 2.13). A pressure transducer and datalogger are used for "continuous" water level measurements. A pressure transducer is a very small device that changes shape proportionally to the pressure applied. In this case, the change in pressure stems from the varying height of the water column above the transducer. The change in shape with changing water level minutely affects the ability of the device to transmit electrical current. These changes in current can be measured and the measurement recorded on a computer chip, which is housed in the datalogger. Because these devices are self-contained and powered by battery, they can be placed within lockable enclosures and/or suspended in a well casing. Although, the suspending cable may slip or batteries may fail, this method is advantageous over hand measurements because the equipment is well-suited for use at remote locations.

The transducer and datalogger can be programmed to measure and record at various time intervals from a few seconds to a several hours. This allows the datalogger to be programmed to capture the effects of temporal fluctuations caused by nearby cyclical pumping or recharge events that are missed by one-time or spot hand measurements. The datalogger files are read periodically (monthly or quarterly) by field personnel. If the initial or final depth of the datalogger or depth to water are known, then the readings can be converted to depth to water at the time of measurement and data collection.

A second method is to measure the water level directly either using a chalked, steel measuring tape that or an electronic measuring line. When wetted, the chalked length is darkened and the length of submerged tape is known. The wetted length is then subtracted from the total length of tape placed in the well and the depth to water from the measuring point is determined. An alternate method is to use a thin wire with a sensing probe. When the probe contacts the water, a battery-powered circuit is completed and an indicator (light, gauge, or beeper) activates. In most cases, the length is marked on the thin wire, and the depth to water is recorded in the field notes. While not as prone to electrical malfunctions, easily verifiable, and relatively cheap compared to pressure transducers, these methods only provide a single point-in-time measurement.



Hand Measurement with Electronic Line

Pressure Transducer Installation

Figure 2.13 Water Level Measurement Methods and Resulting Hydrographs

Figure 2.13 shows a portion of a hydrograph collected using a pressure transducer and using hand measurements. In practice, hand measurements are collected at the time that water quality samples are taken, during the installation of transducers and download of transducer-produced data, and "as-needed" to ensure that transducer data is accurate. As shown in Figure 2.13, rises and peaks were missed using just the quarterly hand measurements and even the more frequent USGS hand measurements, which are also shown for comparison. The hydrograph in Figure 2.13 also indicates two common ways of presenting the water level data, either as depth to water or as the elevation relative to mean sea level (i.e. above mean sea level or amsl).

1.4 ***Water Quality Monitoring and Analyses***

Bernalillo County-selected water quality parameters have historically included volatile organic compounds, semi-volatile organic compounds, major anions and cations, nutrients (primarily nitrogen compounds), metals and total dissolved solids. USGS programs being conducted in the same or overlapping areas are targeted to specific objectives, but analyses generally include major anion and cations, or in the case of assessment-type surveys, have included volatiles, semi-volatiles, and pesticides, or wastewater specific organic compounds. Typically, Bernalillo County collects samples from the wells but contracts for analytical services from local laboratories and, in some instances, from the USGS.

The analyses for major anions and cations, trace metals, and total dissolved solids allows for determining differences in naturally occurring regional water chemistry and provides important water quality information related to potability and irrigation use for selected regions of the unincorporated areas of Bernalillo County. The data are also useful for determining the area of recharge for a spring or well. The analyses for major anions and cations, along with metals also help determine if there are septic-related water quality problems within Bernalillo County. The analyses for volatile, semivolatile, and herbicide/pesticide-related compounds are useful for determining the presence and extent of contaminants stemming from particular land use practices such as agricultural discharges, underground storage tanks or other industrial / commercial uses.

1.4.1 *Water Quality Analysis and Quality Assurance*

Analyses discussed in Section 3 are taken from a variety of sources with differing degrees of quality control and utilizing differing analytical techniques. The overarching scope and the general nature of this report did not warrant a quality assurance audit or extensive quality assurance protocols. This report assumes that data provided from Bernalillo County databases, the USGS database, and the CABQ database are suitable for general use and are generally comparable.

Field notes for the Bernalillo County sampling events prior to 2004 could not be located in the file. However the files do indicate that the Bernalillo County analyses were conducted by State of New Mexico laboratories or by commercial laboratories utilizing standard methods and protocols. A review of the available analytical certificates did not note any significant quality issues. The quality of the USGS data are generally traceable through the on-line database and considered reliable. The CABQ provided a copy of their database in electronic form and no QA/QC information was requested or provided. The CABQ data was checked for reasonableness prior to use, with data adjustments made as described in the following paragraphs. Aside from a general reasonableness check for anomalous values, no independent checking of reported concentrations from outside agencies has occurred. None of the supplied data have been rejected.

The data sets were plotted and scanned to identify where units of measure appeared inconsistent (i.e., metals values reported as ug/L rather than mg/L) – in such instances where a simple conversion would result in a concentration consistent with previous or following data, the conversion was made to the data set. Similarly, reported bicarbonate values were reviewed to determine whether the reported values were reported as bicarbonate (HCO_3) or as calcium carbonate ($CaCO_3$) – all values were converted to represent the analysis as bicarbonate. This same approach was taken for nitrate (as N) and nitrate (as NO_3), with all analysis being converted to nitrate (as N).

In the event of conflicting values (e.g., calcium might be reported using two different techniques for a single sample), the higher concentration was used to ensure that reported values were protective of public health. In the case of graphs showing meq/L, this means that anion-cation balances may exceed agreement of 10 percent in some instances, and data distributions could potentially be skewed by acceptance of excessively high or low values that might otherwise have been rejected.

This also raises the potential for the data range and distributions to be slightly skewed to high concentrations. Again, this is acceptable because it is conservative and minimizes risk to the public.

The report also “lumps” data resulting from varying field and analytical techniques such as filtered and unfiltered samples used for metals analysis. In most cases, this makes minimal difference but it may be significant for iron, manganese, and aluminum due to the properties of these metals and their presence in sediments and colloids that are removed by filtering prior to acidification. In determining data distributions, the calculations use the reported detection limit as a surrogate concentration for those parameter concentrations where the result is reported as “less than detection limit”. This sometimes leads to the appearance that a constituent was detected while in actuality it was not, which can affect the trace metals distributions where non-detects at low concentrations are a common occurrence. Again, this approach is acceptable because it is conservative with respect to public health issues and regulatory compliance is not a consideration for the purposes of this report.

1.4.2 *Comparison to U.S. EPA Drinking Water Standards*

In many instances, comparison will be made to U.S. EPA’s National Primary and Secondary Drinking Water Standards (40 CFR Part 141). Tables 2.1a and 2.1b provide a listing of the Primary and Secondary Drinking Water Standards for metal and inorganic constituents. With only a few exceptions as noted in the text below, samples analyzed for organic constituents yielded non-detects (i.e., reported as “less than” a stated detection limit for organic constituents). Consequently, Table 2.1 does not list the regulated organic contaminants.

The National Primary Drinking Water Standards are expressed as Maximum Contaminant Levels (MCLs) for a prescribed list of compounds. The MCLs have been promulgated based on the potential for health-based effects and costs of treatment and availability of treatment technology. They are used to limit the levels of contaminants in public water supplies. While these standards are enforceable standards only for public water supply systems, they are useful for providing a quantitative measure of water quality. Maximum Contaminant Level Goals (MCLGs) are also health-based standards. MCLGs are concentrations below which there is no known or expected health risk. The MCLGs are non-enforceable and are more restrictive than the MCLs; therefore, this report does not use the MCLGs as a basis for comparison though the reader may make such a comparison using the values for the MCLGs given in Table 2.1.

The National Secondary Primary Drinking Water Standards (or Secondary Standards) are not enforceable guidelines. The Secondary Standards are set based on the potential for cosmetic effects (e.g., tooth discoloration) or aesthetic effects (e.g., taste, odor, or color). The Secondary Standards quantify a potential “nuisance” threshold for groundwater users and the report, therefore, uses the Secondary Standards as a basis for comparison.

Table 2.1a Primary Drinking Water Standards for Inorganic Parameters

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Antimony	0.006	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic	0	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes
Asbestos (fiber >10 micrometers)	7 million fibers per liter	7 MFL	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits
Barium	2	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	0.004	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium	0.005	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chromium (total)	0.1	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper	1.3	TT Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide (as free cyanide)	0.2	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories
Fluoride	4.0	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories

Table 2.1a Primary Drinking Water Standards for Inorganic Parameters (continued)

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Lead	zero	TT Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury (inorganic)	0.002	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands
Nitrate (measured as Nitrogen)	10	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as Nitrogen)	1	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Selenium	0.05	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	0.0005	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories

Table 2.1a Primary Drinking Water Standards for Inorganic Parameters (continued)

Contaminant	MCLG (mg/L)	MCL or TT (mg/L)	Potential Health Effects from Ingestion of Water	Sources of Contaminant in Drinking Water
Alpha particles	none ---------- zero	15 picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation
Beta particles and photon emitters	none ---------- zero	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation
Radium 226 and Radium 228 (combined)	none ---------- zero	5 pCi/L	Increased risk of cancer	Erosion of natural deposits
Uranium	zero	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits

Notes

Source: http://www.epa.gov/safewater/mcl.html#mcls last visited on 3/09/06

[1] Definitions:

Maximum Contaminant Level (MCL) - The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
Maximum Contaminant Level Goal (MCLG) - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
Maximum Residual Disinfectant Level (MRDL) - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
Maximum Residual Disinfectant Level Goal (MRDLG) - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
Treatment Technique - A required process intended to reduce the level of a contaminant in drinking water.

[2] Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

Table 2.1b Secondary Drinking Water Standards for Inorganic Parameters

Constituent	Secondary Contaminant Level
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	Noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

1.4.3 *Water Quality Presentation Formats*

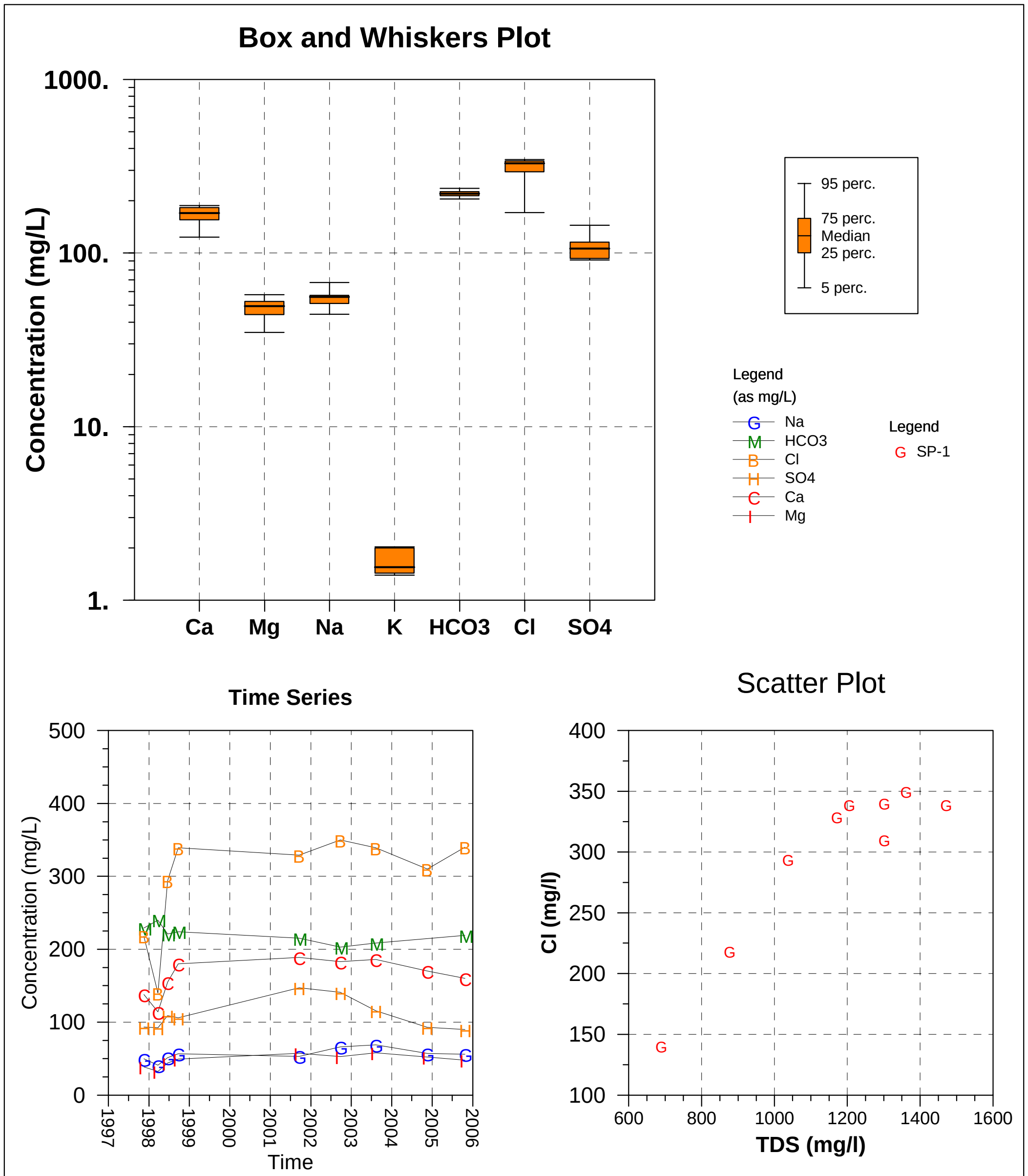
Various methods to illustrate and plot water quality information are used throughout this report: Box and Whisker diagrams, time series plots and scatter plots are used to illustrate composition and trends. Throughout, analyses are expressed in units of mg/L unless otherwise specified. Piper plots, Stiff diagrams, and pie charts are used to illustrate composition based on "combining weights" or milliequivalence per liter (meq/L). The concept of equivalence or "combining weight" takes into account the electrical charge of the individual ions and the formula weight of each ion. The equivalence concentration is determined by multiplying the mass concentration (mg/L) by the valence of the ion and dividing by the formula weight. Table 2.2 provides an example data set expressed as both mg/L and as meq/L.

<u>Box and Whisker diagrams</u> (Figure 2.14) are useful for showing a statistical summary and distribution of available concentration information. The graph provides a quick way to summarize the data and to compare one group of samples to another, such as the water quality in a given monitoring well to other wells in the area. These distributions are used for comparing water quality for the group to U.S. EPA Drinking Water Standards and provide a quick measure of potential risk to groundwater users.

In this report, the Box and Whisker diagrams are used to show the concentrations relating to various percentile values including the 5^{th} and 95^{th}, the interquartile range represented by the 25^{th} and 75th percentile concentration value, and the median value for a group of samples. The group may define a geographic area (e.g., the East Mountain area), a formation (e.g., the Chinle formation), or a given well (e.g., Sandia Park Well 1). The reported distributions may be biased if a given well has been sampled more or less frequently than other wells included in the group. No weighting based on sampling frequency from a given well has been applied for the group based plots.

Table 2.2 Example Data Set

Parameter Concentration as mg/L						
Sample Date	*Ca*	*Mg*	*Na*	*HCO3*	*SO4*	*Cl*
11/18/1997	138	38.7	49.6	229	93.2	218
3/25/1998	114	32.4	41	240	92.5	140
6/19/1998	155	44.1	51.1	221	109	284
9/19/2001	189	57.2	53.1	215	147	329
9/6/2002	183	52.7	66.1	203	141	350
11/18/2004	170	52	57	- -	93	310
10/25/2005	160	48	56	219	90	340
Conversion to meq / L						
Factor	*0.0499*	*0.0364*	*0.0435*	*-0.01639*	*-0.02082*	*-0.02821*
Parameter Concentration as meq/L						
Sample Date	*Ca*	*Mg*	*Na*	*HCO3*	*SO4*	*Cl*
11/18/1997	6.89	1.41	2.16	-3.75	-1.94	-6.15
3/25/1998	5.69	1.18	1.78	-3.93	-1.93	-3.95
6/19/1998	7.73	1.61	2.22	-3.62	-2.27	-8.01
9/19/2001	9.43	2.08	2.31	-3.52	-3.06	-9.28
9/6/2002	9.13	1.92	2.88	-3.33	-2.94	-9.87
11/18/2004	8.48	1.89	2.48	- -	-1.94	-8.75
10/25/2005	7.98	1.75	2.44	-3.59	-1.87	-9.59



DESCRIPTION:

Example Water Quality Analysis Plots Expressed as mg/L

PROJECT: *Water Report*	DATE: 7/13/2006

BERNALILLO COUNTY PUBLIC WORKS / WATER RESOURCES

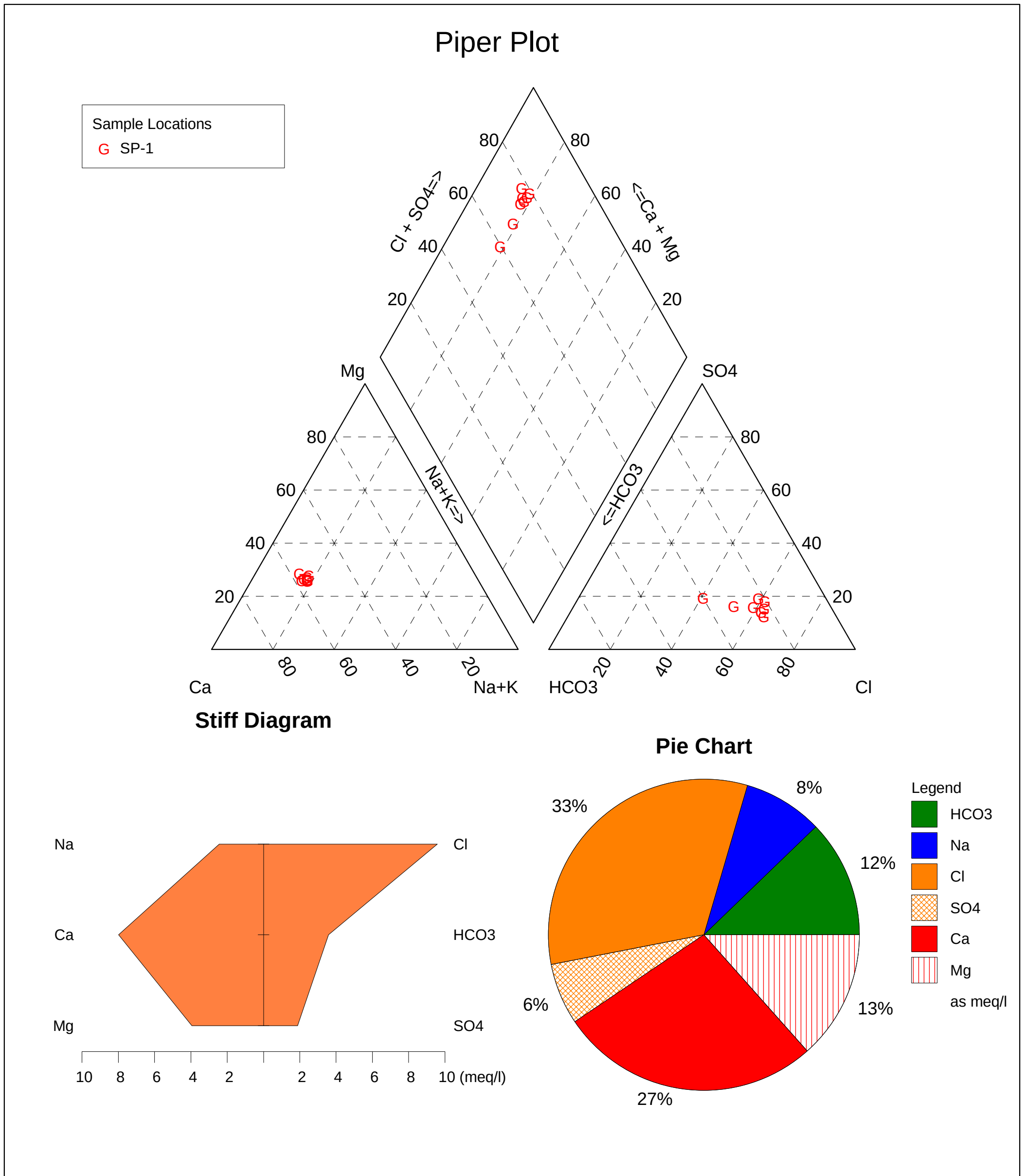
Figure 2.14 Example Plots Expressing Analyses as mg/L

If the median or lesser percentiles (i.e. 10 percentile or 25 percentile) exceed the drinking water standards discussed above, then most of the samples taken from wells within the subject group will exceed the standard at any given time. If the 75th percentile exceeds the standard, then roughly, one out of every four samples pulled from the group will exceed the standard. If only the 95th percentile value exceeds the standard, then it is unlikely, though not impossible, that a sample will exceed the standard. In this example, chloride concentrations exceed a standard of 250 gm/L at the 25th percentile, suggesting three (3) out of every four (4) samples will exceed the standard. In some cases, such as bicarbonate (HCO_3), the distribution in values may be quite narrow.

Time Series plots (Figure 2.14) are useful for showing changes in concentration in time, and identifying if more than one parameter concentration may be changing simultaneously. These plots are essentially simple x-y charts with the x access being time and the y-axis being a measured concentration. In the example, there is an initial rise in chloride concentration and other parameters, but no significant increase after the first sampling event.

Scatter plots (Figure 2.14) are useful for showing the relationship between two parameters. These plots are simple x-y plots with each axis representing a single parameter. Clustering or trends in the data are generally readily identifiable. In the example, a rise in chloride concentration corresponds to a rise in total dissolved solids.

Piper plots (Figure 2.15) are used to show water composition and trends in anion and cation constituents. As succinctly described by the USGS in various papers (Hem, 1989; Bexfield et al., 1999), a water analysis is represented by three points on a Piper diagram, one point in each of two triangles and a point in a diamond-shaped center field (Figure 3.1). The lower left triangle represents the composition of cations (calcium, sodium + potassium, and magnesium), the lower right triangle represents the predominant anions (chloride, bicarbonate, and sulfate). The center diamond presents the intersection point of the projection of the points from the two triangles. The points are plotted in the left and right triangles as the percentage of the individual anion or cation in comparison to the total equivalents of anions or cations.



DESCRIPTION:
Example Water Quality Analysis Plots Expressed as meq/L

PROJECT: *Water Report*

DATE: 7/13/2006

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Figure 2.15 Example Plots Expressing Analyses as meq/L

The left and right triangles can be divided into four areas that indicate the water types of the sample with respect to cations and anions, respectively. The two points are then projected into the central diamond to represent the net composition. Two samples with similar distribution of cations and anions, but with widely varying concentrations would plot at the same locations. In this example, the diagram shows a relatively stable cation composition (Ca, Mg, Na), but the anion composition (Cl, SO_4, HCO_3) has varied.

<u>Stiff diagrams</u> (Figure 2.15) are similar to Piper plots in that they show the relative value of anions and cations in terms of milliequivalents per liter. They have the advantage of visually emphasizing the predominance of particular anions or cations and form distinctive shapes that are visually comparable. However, Stiff diagrams show the composition of only one sample at a time. For this example, the significance of calcium and chloride is readily recognized.

<u>Pie charts</u> (Figure 2.15) are similar to Stiff diagrams and show only one sample at a time. They are similar to Piper plots in that they show the relationship between ions as a percentage. However, the percentage is based on the total milliequivalents of the sample rather than as a percentage of the anions or cations only. Again, the relative importance of calcium and chloride are shown in the example.